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SIDE-SCAN SONAR RECORDS AND DIVER OBSERVATIONS OF THE GRAY WHALE (*ESCHRICHTIUS ROBUSTUS*) FEEDING GROUNDS

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Abstract

Gray whales (*Eschrichtius robustus*) excavate infaunal invertebrates and sediment by suction, producing many large depressions in the sea floor. Diver observations indicate that side-scan sonar provides accurate estimates of the size of feeding excavations and the area of bottom covered by excavations (>30% of the bottom). Although side scan does not detect some excavations because of small size (particularly <3 m^2) or their orientation with respect to the side-scan track, it gives a quantitative impression of the relative intensity of bottom disturbance by whales. This disturbance is directly related to habitat and prey utilization by whales.

Introduction

Gray whales (*Eschrichtius robustus*) extensively excavate the sea floor while feeding on benthic invertebrates (Oliver *et al.*, 1983b, 1984). The major prey are amphipod crustaceans living in bottom sediments (Rice and Wolman, 1971; Zimushko and Ivashin, 1980; Bogoslovskaya *et al.*, 1981). Field observations show that both infaunal prey and sediments are extracted by suction (Oliver *et al.*, 1983b, 1984). (See Ray and Schevill, 1974 for "laboratory" observations of suction.) Sediment is expelled through the baleen. Excavation size and shape are highly variable. Gray whales rework single or multiple feeding excavations into much larger and complex features. Distinct excavations range in diameter from less than 1 m to over 20 m. While some feeding excavations are shallow surface sucks (3–10 cm deep), many excavations are 15–30 cm deep, and some are over 40 cm deep (Oliver *et al.*, 1983b, 1984).

The feeding excavations of gray whales are detected by side-scan sonar (Johnson *et al.*, 1983) and are easily distinguished from other depressions in the sea floor made by walrus (Oliver *et al.*, 1983a), ice gouging (Reimnitz *et al.*, 1977; Thor and Nelson, 1981), and gas craters (Nelson *et al.*, 1979). However, does side-scan sonar accurately represent feeding excavations and provide a useful relative impression of feeding disturbance? We answer this question by comparing side-scan records and diver observations of a highly accessible feeding ground along Vancouver Island, where prey communities and feeding records are remarkably similar to the primary feeding ground in the Bering Sea (Oliver *et al.*, 1984).

Materials and Methods

The major study area was in Pachena Bay on the west coast of Vancouver Island, British Columbia. Gray whales fed in the bay during the spring and summer on a dense community of tube-dwelling *Ampelisca* amphipods (Oliver *et al.*, 1984). Two permanent underwater stations were established in Pachena Bay to compare side-scan records with diver observations from 16 July to 15 August 1983. The two stations represented areas with relatively few and many excavations, and were designated the

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sparse and dense stations, respectively. A 50-m line (marked every 5 m) was staked to the bottom at both sites. The lines were perpendicular to the general direction of sand ripple marks on the sea floor. The ends of the lines were marked with surface buoys and a large metal barrel or beam that gave a distinct trace on record. As a result, each 50-m line could be located on a record and placed within a known pattern of excavations.

The side-scan sonar was a 500 kHz system (Klien 521 dual channel side-scan). Recordings were made on wet paper at 60 lines/cm. All records were made on the 50-m range scale, giving a record with a 50-m width on both sides of the tow fish (a hydrodynamically designed body containing the underwater transducers). The record was uncorrected for ship speed and depth of tow (see below). The fish was towed at a depth of 5–6 m above the bottom (45–60° wire angle), at constant rpm, and at a constant compass direction. We used two boats with deep V-hulls: a 21-foot Lucas (Hurricane 600) and a 40-foot converted Bristol Bay fisheries boat (R/V ALTA). While the side-scan was towed under a variety of sea conditions, quantitative measurements were taken only from records made in seas with <0.5-m swell and no wind chop. Divers placed sea floor targets 50 meters apart within the study area. These were visible on the side-scan displays, allowing the records to be corrected for ship speed. This was done by digitizing the records and redrawing them to the correct scale using a computer.

Diver estimates of percent bottom covered by excavations, mean excavation size, and size distribution of excavations all came from diver maps of the dense and sparse station areas. Parallel estimates were made in several ways from side-scan records. Excavation patterns usually were measured only from a single run over a diver station. If estimates came from a single run, the run is numbered (run 1 or run 2). A composite sample was taken by examining all the single runs over a diver station and locating as many of the diver-observed excavations as possible. Finally, several single runs over the diver stations and over nearby areas were sampled to make regional estimates of excavation patterns. The regional areas were larger than the station area, but still represented the relatively sparse or dense feeding records.

All the underwater observations were done by divers using SCUBA. Divers located and examined all feeding excavations at least 20 m on both sides and at the ends of the 50-m lines. They measured to the nearest 0.5 m the relative position, shape, major dimensions, and depth (to nearest cm) and noted edge conditions (steep or gently sloping) for each excavation. These observations were facilitated by good water clarity (5–8 m). All excavations were less than one month old (Oliver *et al.,* 1984).

Results

The dense and sparse areas were easily distinguished by side scan. The percentage of the sea floor covered by feeding excavations was significantly greater at the dense compared to the sparse station ($P < 0.05$, Mann Whitney U-test). The mean size of excavations was significantly larger ($P < 0.05$, Mann Whitney U-test) at the dense station (Table II). There was also a significantly greater proportion of large excavations at the dense station ($P < 0.05$, Kolmogorov-Smirnov test). In all estimates from the same station, the three samples from side-scan records (single runs, composites, regional samples) were not significantly different from each other ($P > 0.05$, same tests). Finally, the dense study site was not located in the most intensely disturbed feeding area, where we found over 30% of the sea floor covered with feeding excavations.

Quantitative measurements of the feeding record made by divers were similar to quantitative estimates from side-scan records. Diver and side-scan measures of the

TABLE I

Percent area of the sea floor covered with gray whale feeding excavations at the relatively sparse and dense feeding areas in Pachena Bay

	Diving observations	Side Scan* Run 1	Side Scan* Run 2	Side Scan* Composite
Dense feeding station ($6450\ m^2$)	11.7%	9.3%	9.8%	10.8%
Number of excavations	42	31	34	40
Sparse feeding station ($2680\ m^2$)	4.5%	3.4%	4.9%	3.6%
Number of excavations	14	8	11	12

* See Methods section for explanation of single run *versus* composite.
Diver and side-scan estimates are similar.

percentage of bottom covered by feeding excavations were remarkably similar (Table I). There was no significant difference ($P > 0.05$, Wilcoxon's signed-ranks test) between the mean size of excavations estimated by divers and by side scan at either the dense or sparse stations (Table II). At the dense station there was no significant difference ($P > 0.05$, Kolmogorov-Smirnov test) between diver and side-scan estimates of the size distribution of excavations (Fig. 1). However, at the sparse station, there was a significant difference ($P < 0.05$, Kolmogorov-Smirnov test) between diver and side-scan estimates of the size distribution of excavations (Fig. 2). This difference could only be detected when the side-scan records were examined from the entire region around the sparse station. This region was qualitatively similar to the station site, but contained more features. Since our sample size was small at the sparse station (Tables I, II), the regional sample increased the power of the statistical test (Sokal and Rohlf, 1981). Furthermore, this difference could only be established by dividing the excavation area into $1\ m^2$ size classes rather than $5\ m^2$ (Fig. 2).

Smaller excavations were more difficult to detect on side-scan records (Table III). At the dense station, only two excavations were never located on the records, both were $<3\ m^2$. Eighteen excavations between 3 and $13\ m^2$ were missed on at least one record at the dense station. No excavations larger than $13\ m^2$ were missed on records from either station (Table III).

TABLE II

Mean size (m^2) of excavations estimated by divers and side scan in the relatively dense and sparse feeding areas in Pachena Bay (± standard errors)

	Diving observations	Side scan* Run 1	Side scan* Run 2	Side scan* Composite
Dense feeding station ($6450\ m^2$)	18.0 ± 2.6	18.1 ± 3.4	18.6 ± 2.6	17.4 ± 2.4
Number of excavations	42	31	34	40
Sparse feeding station ($2680\ m^2$)	8.6 ± 2.8	11.5 ± 3.2	12.0 ± 3.3	8.0 ± 3.2
Number of excavations	14	8	11	12

* See Methods section for explanation of single run *versus* composite.

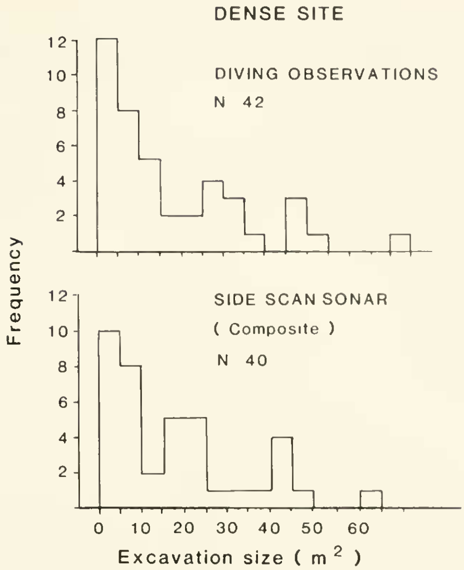

FIGURE 1. Size distribution of feeding excavations measured by divers and from side-scan records (a composite sample) at the dense station.

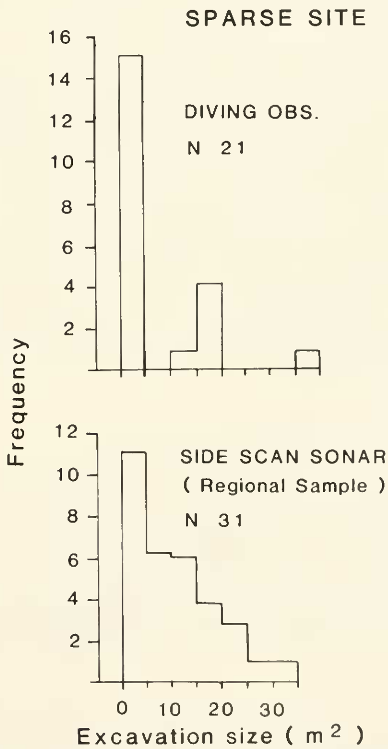

FIGURE 2. Size distribution of feeding excavations measured by divers and from side-scan records (regional sample) at the sparse station.

TABLE III

The ability of side scan to detect relatively small (<13 m²) or large excavations (>13 m²)

	<13 m²		>13 m²	
	Never seen	Missed at least once	Never seen	Missed at least once
Dense feeding area	9%	43%	0%	0%
Number of excavations	23		19	
Sparse feeding area	27%	78%	0%	0%
Number of excavations	9		5	

Only a few excavations were never located by side scan; more were missed on at least one run over the station areas.

DISCUSSION

Side-scan sonar can give an excellent impression of the relative intensity of gray whale feeding in soft-bottom habitats. Some feeding excavations are undetected because of their small size or orientation to the sonar signal. Nevertheless, side-scan and diver estimates of excavation sizes and the percent area disturbed show the same relative differences between a dense and a sparse feeding record, even when the dense and sparse records were relatively similar. The feeding record is quantified more precisely and easily, and for large areas more effectively, from records than from diver observations.

Side-scan sonar has considerable potential as a tool for documenting feeding patterns of gray whales. Spatial and temporal variations in the relative intensity of feeding can be documented. Ideas about large-scale patterns of habitat and prey utilization can be tested. Side scan also has applications in future management of bottom-feeding marine mammals such as the gray whale, and perhaps the walrus (Oliver *et al.*, 1983a). Just as the browse patterns of deer and other ungulates are used by terrestrial biologists (de Voos and Mosby, 1971), excavation patterns documented by side scan can help to assess the interactions between large marine grazers and their benthic food. The most important contribution of side-scan sonar to future management may be in evaluating long-term ecological questions involving the exploitation of peripheral and central feeding grounds as the gray whale population grows, stabilizes, or declines in size.

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